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EFFECTS OF FREEZING AND COLD WEATHER ON IMMATURE ONIONS[1]

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INTRODUCTION

Rarely is there such an opportunity to study the response to freezing and cold weather of a large number of onion varieties in a vigorously vegetative condition as was presented in 1933 at the Winter Garden substation of the Texas Agricultural Experiment Station (Texas Substation No. 19, at Winter Haven, Dimmit County). In the first place, the weather conditions were very unusual; and in the second place, a very complete collection of the more important varieties grown in the United States chanced to encounter these abnormal weather conditions.

MATERIALS AND METHODS

The strains of the varieties used (see table 2) were in most cases seed growers' stock supplied to the United States Department of Agriculture for use in connection with the descriptions of types of the principal American varieties of onions, on which the writers are collaborating with a number of workers at other experiment stations. Some strains were obtained from the California and Utah Stations.

With the exception of the Bermuda varieties, the seed for these trials were sown in an open seed bed on September 14 and transplanted in triplicate to a permanent field location on November 18, 1932. The seed of Yellow Bermuda and Crystal Wax were sown in a similar way on September 20 and transplanted on December 8. The common commercial practices of the district were followed wherever possible in the handling of this crop. This field, however, received 1,200 pounds to the acre of a mixed fertilizer having the formula 6–12–3[2] instead of the usual commercial application of 600 to 900 pounds per acre of 6–12–6.

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[1] Report of cooperative investigation by the Bureau of Plant Industry and the Texas Agricultural Experiment Station.

[2] Percentage of nitrogen, phosphoric acid, and potash, respectively.

WEATHER AND GROWTH CONDITIONS

The freezing weather which made the study possible occurred on February 8, 9, and 11, 1933. January 1933 was unusually warm, with a mean temperature of 60.1° F., as compared with a normal of 53.0, although minima of 23, 32, and 34 were recorded on January 1, 2, and 14, respectively. The weather as a whole during January and early February was very conducive to rapid growth of most vegetation. Trees and shrubs normally dormant at that time of year were bursting their buds. The 1½ inches of rain during the first week of February (table 1) speeded up the growth rate of the onions and resulted in a succulent condition at the time of the first freeze. In general, growth had been better than average throughout the district. This particular planting was in excellent condition, and by February 7 the plants had attained a height of about 50 cm and a diameter of 15 to 20 mm just above the ground level.

Table 1.—*Meteorological data for February 1933 at Winter Haven, Tex.* [1]

Day of month [2]	Air temperature		Precipitation	Average relative humidity	Evaporation (actual)	Wind		Weather conditions
	Maximum	Minimum				Total movement	Prevailing direction	
	° F.	*° F.*	*Inches*	*Percent*	*Inches*	*Miles per day*		
1	76	50	---------	60.5	0.091	52	S.	Clear; no dew.
2	74	48	---------	86.0	.068	60	SE.	Partly cloudy; fog.
3	69	52	1.40	94.0	.002	95	NE.	Cloudy; thunderstorm.
4	64	52	---------	82.5	.058	78	SW.	Partly cloudy; no dew.
5	63	50	Trace	78.5	.048	61	SE.	Cloudy; no dew.
6	59	48	.12	93.5	.051	129	NE.	Cloudy; norther.
7	67	50	.03	83.5	.086	106	NE.	Partly cloudy; norther.
8	48	18	---------	43.0	.200	157	N.	Clear; norther.
9	38	21	---------	75.5	.115	165	E.	Partly cloudy.
10	57	34	---------	77.0	.055	126	NW.	Partly cloudy; heavy dew.
11	55	26	---------	68.0	.036	61	SE.	Clear; norther.
12	62	32	---------	76.5	.099	122	SE.	Cloudy; no dew.
13	71	50	---------	78.5	.014	33	SE.	Do.
14	68	53	---------	92.0	.014	63	NW.	Do.
15	65	43	.49	90.0	.042	68	NW.	Cloudy; raining.
16	66	41	.47	89.0	.065	89	S.	Partly cloudy.
17	70	52	Trace	86.0	.050	103	SE.	Do.
18	68	45	---------	73.5	.055	65	S.	Clear; heavy fog.
19	68	55	---------	76.5	.065	87	NW.	Partly cloudy; fog.
20	70	47	---------	42.0	.110	71	NW.	Clear; no dew; norther.
21	72	43	---------	56.5	.174	121	SE.	Partly cloudy; no dew.
22	76	50	---------	70.5	.071	75	SE.	Clear; no dew.
23	82	52	---------	75.5	.049	75	SE.	Partly cloudy; heavy dew; fog.
24	88	60	---------	70.5	.109	180	SE.	Clear; dew.
25	84	63	---------	80.5	.076	128	NE.	Cloudy; no dew.
26	70	51	.32	100.0	.098	86	NW.	Cloudy; raining.
27	71	49	.22	67.5	.099	139	NW.	Partly cloudy.
28	68	42	---------	70.0	.116	70	NW.	Clear; heavy dew; norther.

[1] Standard U. S. Weather Bureau instruments and shelters used.
[2] Day beginning and ending at 6 p. m.

A cold wave began on February 7, and by 9:30 p. m. on that date the temperature had dropped to 31° F. This drop in temperature was accompanied by a high wind which blew all night. Sometime during the early morning of February 8 the temperature reached the low of 18° and at 9:30 a. m. it had not risen above 21°. The maximum for that day was 48°. The night of February 8 and early morning of the 9th was again characterized by high winds and low temperature, a low of 21° being recorded. During the balance of the day the temperature failed to go above 38°. Low temperatures continued for 3 more days, although maxima of 57° and 55° were recorded on February 10 and 11. On the 11th the temperature again went below freezing, reaching a minimum of 26°, and on the morning of the 12th it registered a minimum of 32°.

Following this cold wave the temperature rose rapidly to normal, and before the end of the month there were 3 successive days with maxima of over 80° and minima between 52° and 63°. Good rains fell on the 15th and 16th and again on the 26th and 27th, which without doubt contributed greatly to the subsequent recovery of the frozen plants. March weather was fairly normal and no more freezes occurred.

RESULTS OF FREEZE

Following the freezing temperatures of February 8 and 9 the tops of the onion plants collapsed and lay flat on the ground. This prostrate condition continued for a number of days, and many of the old leaves never recovered. Growth was resumed mostly by the sending out of new leaves. By the end of February most of the onions that were not killed by the cold were looking vigorous and healthy again. The rate of recovery was approximately equal for all varieties, although, as the data in table 2 indicate, fewer plants survived in some varieties than in others. In spite of the set-back the Bermuda onions matured only slightly if any later than usual.

Yellow Bermuda onions of a different seed source from that of those in this study had been planted on adjacent ground at 10-day intervals during the fall months of 1932. All of those sown on and after November 19 were killed by the freeze of early February. None of them had been transplanted.

Since the seriousness of most cold waves is often judged by the extent to which vegetation is injured, a statement regarding the damage to crops other than onions follows. Those vegetables killed outright were cauliflower, heading broccoli, sprouting broccoli, and garden peas. Although not completely killed in all instances, the following vegetables were so badly injured that they were a total loss: Lettuce, mustard, chicory,[3] turnips, beets, and kohlrabi. In the case of the root crops listed, if the root was not exposed above the ground it was usable for local consumption for a week or more after the freeze. Vegetables which could still be used, although slightly injured, or which rapidly grew out of their injured condition were kale, brussels sprouts, parsnips, and spinach. Common dandelion, carrots, and some cabbage were still marketable immediately after the freeze, although the foliage of the carrots showed a slightly "burnt" condition a week later.

Many fruits and ornamentals which were bursting their buds or already in leaf and bloom were severely injured. Grapefruits, calamondins, sour oranges, Meyer lemons, nearly all oranges except Satsumas, and most avocados were frozen to the ground. Kumquats came through undamaged. Strawberries lost all their flowers and fruit, of which there was a heavy set, and a few plants were killed. Sap was flowing in many native trees and shrubs, and most of these were severely frozen back, though few as far as the ground, and none were completely killed.

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[3] *Cichorium intybus* L.; known locally as Italian dandelion; not the common dandelion, *Taraxacum officinale* Weber.

Most herbaceous flowering plants were injured similarly to the vegetables. Few survived and fewer came through unscathed.

The data on the onions (table 2) are based on counts made from May 10 to 12, at which time the Bermuda types had already matured. The other varieties were still several weeks from harvest.

TABLE 2.—*Effect of freezing on percentage of stand, doubles, multipliers, and seeders in 20 varieties of onions, Winter Haven, Tex., 1933*

[Except as otherwise noted, figures are averages of 2 replications, each usually containing from 100 to 150 plants]

Variety	Strain no.	Stand	Doubles	Multipliers	Seeders
		Percent	*Percent*	*Percent*	*Percent*
Yellow Bermuda	1	34.4	10.6	6.7	0.0
	[1] 2	70.8	7.4	1.6	.0
	[1] 3	65.9	9.1	2.5	.0
	4	62.4	4.3	1.0	.0
Crystal Wax	1	78.2	35.7	.8	1.6
	2	69.0	22.4	.0	1.6
	[1] 3	71.7	25.6	.8	.0
	4	71.6	14.6	.4	1.2
California Early Red	[2] 1	58.2	.0	.0	.0
	[1] 2	75.4	1.0	.5	.0
Italian Red	[1] 1	80.3	.6	5.9	.0
Extra Early Yellow	1	68.2	.4	1.3	.0
Prizetaker	1	75.0	3.4	1.3	.0
	2	82.1	7.3	2.2	.0
	3	78.1	1.8	.7	.0
Sweet Spanish	1	76.3	2.5	.0	.0
	2	74.6	1.9	.0	.0
	3	82.6	3.3	.0	.3
	4	65.1	2.1	.5	.0
	5	81.1	.4	1.2	.0
	6	81.0	.4	.4	.0
White Sweet Spanish	1	91.2	5.2	.7	.7
Ebenezer	1	86.1	15.5	2.1	.0
	2	90.5	12.5	.0	.0
	3	84.5	14.4	.5	.0
	4	91.1	8.2	1.2	.0
Yellow Strasburg	1	83.5	6.8	.0	.0
	2	93.5	13.2	.0	.0
White Portugal	1	94.8	11.8	.0	.0
	2	96.2	11.9	.0	.0
	3	99.7	5.4	.0	.0
Yellow Danvers Flat	1	90.4	5.8	.7	.0
Red Wethersfield	[1] 1	85.2	3.1	2.5	.0
	[1] 2	80.8	3.4	.7	.0
	[1] 3	95.0	1.1	.0	.0
Mountain Danvers	1	93.5	2.0	.0	.3
	2	95.8	2.5	.0	.0
Southport White Globe	1	91.5	3.0	.0	.0
	2	94.3	4.1	.6	.3
	3	76.4	6.4	.0	.0
Southport Red Globe	1	88.8	1.0	.7	.0
	2	89.6	1.8	.9	.0
	3	95.7	.3	.3	.0
Southport Yellow Globe	1	88.7	.3	.7	.0
	2	99.4	.6	.0	.0
	3	96.1	.3	.0	.0
Australian Brown	1	90.2	.4	.4	.0
	2	92.6	.7	.3	.0
	3	80.4	.5	.0	.0
	4	88.2	1.4	.0	.0
Yellow Globe Danvers	1	71.7	.4	.8	.0
	2	94.0	.4	.4	.0
	3	86.3	.8	1.3	.0
Ohio Yellow Globe	[2] 1	90.8	.0	1.7	.0
	2	88.1	.8	.0	.0

[1] Based on 3 replications.

[2] Based on 1 replication.

Soon after the freeze it was apparent that there were consistent differences between the varieties in the number of plants killed by the freeze and by subsequent cold weather. No record was made of the stand just prior to the freeze, but since it was almost a perfect stand, the greater part of the differences shown in table 2 are thought to be varietal. Yellow Bermuda and Crystal Wax lost the greatest percentage of plants, closely followed by California Early Red, Extra Early Yellow, and Italian Red. All of these are soft or coarse-textured varieties that do not keep long after harvest. Observations in nearby commercial fields of Yellow Bermuda and Crystal Wax, the only varieties grown in this locality, showed losses as great as these. Next in tenderness were Prizetaker and Sweet Spanish or Valencia. Marked differences were found between strains of the same variety; Yellow Bermuda 1, Southport White Globe 3, Australian Brown 3, Yellow Globe Danvers 1, and Sweet Spanish 4 having much greater losses than the average for the variety. Part of these differences may have been due to chance variation, but no doubt the greater part was due to inherent weakness or the inability to withstand low temperatures.

Under the term "doubles" are included all plants that developed more than one distinct bulb and included misshapen bulbs that were the result of more than one bulbil developing even though the outer scales had not broken (figs. 1 and 2). While doubling and splitting may not be entirely the result of the low temperatures in this case, it is, no doubt, greatly influenced by growth conditions and is a factor of importance to the grower, since these bulbs cannot be included in U. S. No. 1 grade. In general, the flatter varieties produced the greater percentages of doubles, the exceptions being Extra Early Yellow and California Early Red. Crystal Wax had the highest percentage of bulbs of this type and in many cases produced 3 and 4 bulbs from one plant (fig. 1). Ebenezer had the second highest percentage of doubles. The great differences found in the strains of Crystal Wax, White Portugal, Yellow Strasburg, and Ebenezer would seem to indicate that at least a part of this tendency is inherent and might be partially eliminated by selection.

A distinct type of plant designated as "multiplier" was noted separately in making the plant counts. The name is descriptive, as 4 to 15 small shoots with unswollen bases developed from the single stem plate or root plate (fig. 2, *A*). The freeze had apparently killed all the bulb scales down to the stem plate, which then developed several axillary buds. Since the outer usually enveloping scales were dead, a cluster of plants instead of one developed. These were valueless to the grower, but the number of such plants were small except in the case of Yellow Bermuda and Italian Red.

The number of plants with seed stalks, designated as "seeders", was very small. Crystal Wax was the only variety with any appreciable number of seeders. Approximately 1 in 300 was found in one strain each of Southport White Globe, Mountain Danvers, and Sweet Spanish, and 2 in 300 in White Sweet Spanish. None were present in the other varieties. The number of seeders in surrounding commercial fields of Yellow Bermuda was also similarly low, although splits and doubles were conspicuously present.

C. L. Isbell, of the Alabama Agricultural Experiment Station, in a letter to the senior writer dated March 22, 1934, supplied the following previously unpublished data on the resistance of onion varieties to damage from low temperatures. The onions were started from seed in the open at Auburn, Ala., September 20, 1929.

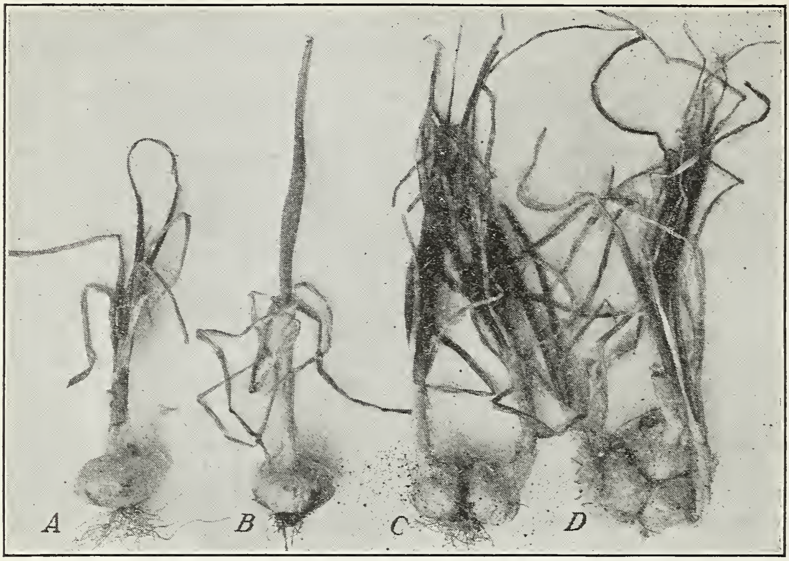

FIGURE 1.—Types of plants found in Crystal Wax variety of onions at Winter Haven, Tex., in May 1933: *A*, Normal; *B*, seed stalk with abortive flower head; *C*, a double; *D*, a triple.

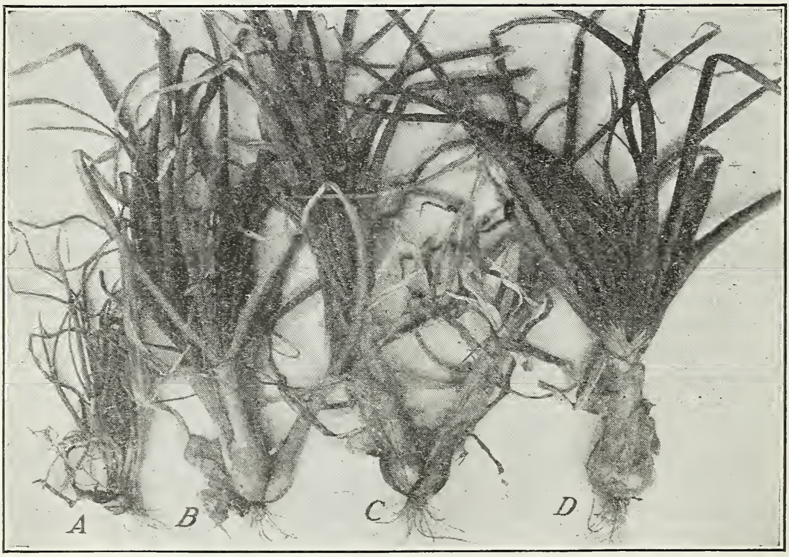

FIGURE 2.—Types of plants found in Ebenezer variety of onions at Winter Haven, Tex., in May 1933: *A*, Multiplier; *B*, quadruplet; *C*, double; *D*, normal.

Variety	Percentage killed by low temperatures [4]
Ailsa Craig	[5] 98
Australian Brown	[5] 95
Creole Red	5
Crystal White Wax	2
Early Red Wethersfield	0
Early White Queen	99
Ebenezer or Japanese (sets)	65
Extra Early White Pearl	[5] 100
Egyptian or Perennial Tree (sets)	[5] 0
Early White Barletta	[5] 100
Ohio Yellow Globe	0
Southport Red Globe	80
Southport White Globe	0
White Multiplier (sets)	15
White Portugal	0
White Wax Bermuda	5
White Bunching	[5] 100
White Globe Danvers	15
Yellow Potato (sets)	35
Yellow Prizetaker	[5] 99

Cold damage to green onions planted August 15, September 1, and October 1, 1932, resulting from a temperature of 11° F. on February 9, 1933, at Auburn, Ala., was as follows:

Variety	Nature and extent of damage
Bermuda (from sets)	All foliage killed. Base of foliage not out of sheath killed to surface of soil. No plants entirely killed. Growth starting within 10 days after the freeze.
Perennial Tree (local selection).	About two-thirds of each leaf killed, the killing tending toward terminal part of leaf. Base of leaves not damaged. No plants killed. Freeze injury not very noticeable 10 days after it occurred.
White shallots	Damage similar to Perennial Tree just above and only about half as much.
Perennial Tree (as commonly cataloged)	From 1 to 4 (average 2 to 3) of the basal leaves killed or at least dead 10 days after the freeze. No apparent damage to younger leaves. Tips of medium-sized leaves killed. It is possible that older leaves were mature and almost ready to die. General conditions of plants 10 days after the freeze indicated that there was little real damage.
Yellow shallots	Same as Perennial Tree just above.
White Multiplier	Tips of leaves killed; not many plants, but apparently not much damage.

In these observations Crystal White Wax and White Wax Bermuda were almost as hardy as some of the domestic varieties and more hardy than others (Southport Red Globe and Yellow Globe Danvers). The European varieties (Ailsa Craig, Early White Queen, Extra Early White Pearl, and Early White Barletta) were most severely damaged and the Perennial Tree, Multiplier, and shallots the least damaged. The hardiness of the Bermuda variety is attested by its survival of a temperature of 11° F. February 9, which killed all of the tissue aboveground.

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[4] Minimum temperature for low periods during the winter were: Nov. 30, 18°; Dec. 1, 20°; Dec. 3, 18°; Dec. 4, 20°; Dec. 18, 23°; Dec. 20, 21°; Dec. 21, 21°; Jan. 19, 16°; Jan. 23, 20°; Jan. 24, 19° F.

[5] Apparently the soil where these varieties grew was not as fertile as where other varieties grew.

DISCUSSION

These data are published not because it is unusual for growing onions to survive temperatures as low as 18° F., nor merely to record the data on varietal reaction, but to encourage additions of similar data to the very meager literature on the cold resistance of growing vegetable crops.

In reporting a comparison of strains of the White Lisbon and White Welsh varieties for resistance to white rot (*Sclerotium cepivorum* Berk.) at North Lancashire and mid-Cheshire, England, Smith [6] states:

> * * * after several weeks of severe frost—the lowest record temperature on the ground having been 4° F.—it was found that all varieties at both centers had practically succumbed, except two lots of White Welsh plants, which appeared to be quite unaffected and perfectly strong and healthy and firmly established in the ground.

If White Welsh is the same as the variety commonly sold in the United States under that name, it is *Allium fistulosum* L., whereas White Lisbon is *Allium cepa* L. Most of the *Allium* species are perennial, but few in their natural habitat are vigorously vegetative during the cold season of the year.

The varieties most commonly grown in the Winter Garden district of Texas, Yellow Bermuda and Crystal Wax, proved to be the most susceptible to freezing injury. Next in susceptibility were the varieties of relatively recent introduction from Italy and Spain, such as California Early Red, Italian Red, Sweet Spanish or Valencia, and Prizetaker. In the countries of their origin they seldom encounter the low temperatures which frequently occur during the early growing period in our domestic onion-growing districts. This point, together with the differences between strains of the same variety, indicates that resistance to cold injury is partially inherent in the variety.

Investigators of the hardiness of other crops have pointed out that many factors besides inherent capacities influence the survival of plants to cold. Among these are length of exposure, degrees of cold, number of times frozen and thawed, rate of thawing, temperature of the dew point at time of freeze, stage of development (age and size), rate of growth preceding freeze, moisture and wind conditions following freeze, soil moisture, and variety of crop. Data are not available on all these points for onions nor for this particular study, but most of the conditions commonly believed to be favorable for injury existed at the time of this freeze. The plants were growing rapidly as the result of favorable air and soil temperatures, the drop in temperature was rapid, the minimum attained was low, the air temperature was below freezing for at least 12 hours the first day, the plants were alternately frozen and thawed three times, they were exposed to a desiccating wind while freezing and thawing, and following the last freeze they thawed rapidly. The particular size of plant and an abundance of soil moisture were probably favorable for recovery. Larger plants in other plantings of the Yellow Bermuda variety were not as severely injured as smaller plants.

Bermuda onions previously have encountered temperatures lower than 18° F. in the same district, as a study of the minimum temperatures at Eagle Pass, Tex., [7] for the past 18 years shows. The weather observers' notes on crop damage are very general and fragmentary, and since complete loss was not recorded in any instance it is assumed that a part of the plants survived. On February 2, 1917, a minimum temperature of 17° was reached and a note made: "Cabbage and onions badly damaged." A low of 15° was reached on the successive nights of January 11 and 12, 1918, and resulted in "badly injured hardy truck crops." At Encinal, Tex., on January 4, 1911, a low of 13° was recorded and "severe damage to truck crops" noted.

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[6] SMITH, E. H. AUTUMN-SOWING VARIETY OF ONION RESISTANT TO FROST AND WHITE ROT. Gard. Chron. 86: 429–430, illus. 1929.

[7] MORTENSEN, E. POSSIBILITY OF FROST DAMAGE TO CITRUS IN THE WINTER GARDEN AREA (giving important minimum temperatures for seasons 1905–6 to 1932–33). Winter Gard. Jour. 1: 4–5, 6. 1933.

January 1930 brought below-freezing temperatures to most of Texas for a number of days.[8] At Eagle Pass the minimum temperatures for the dates January 15 to 24, inclusive, were 25°, 26°, 17°, 17°, 35°, 20°, 12°, 13°, 24° F. At other points in the same section (Winter Garden district) the temperatures were of the same magnitude for this period; Dilley had a low of 15° on the 18th, Carrizo Springs 13° on the 23d, La Pryor 10° on the 22d. Fort McIntosh in the Laredo district had 16° on the 23d; Raymondville had 21° on the 21st; Harlingen, Mercedes, and Mission had 22° on the 23d, and Corpus Christi 14° on the 18th. Frost and freeze damage to truck crops in Texas as reported January 29, 1930, by the Division of Crops and Livestock Estimates, Bureau of Agricultural Economics, United States Department of Agriculture,[9] was as follows:

> Onions: In the Laredo district tops were damaged and growth retarded but they are coming back. Considerable loss of leaves has been reported in the Winter Garden District but these are coming back. The loss at Cotulla is estimated to be 15 percent. Raymondville had considerable loss; in the Corpus Christi area tops were frozen down but are coming back. The total loss to date is estimated at approximately 500 acres. There is ample moisture in the non-irrigated areas. With favorable weather from now on the effect of the damage will probably be to impair quality of early onions and delay harvest from ten days to two weeks.

In March 1932 the Winter Garden district suffered freezing weather 4 days in succession,[10] from the 9th to 13th, inclusive, the minimum of 28° F. being reached at Carrizo Springs on the 10th, 27° on the 10th at Dilley, 26° at Eagle Pass on the 12th, and 25° at La Pryor on the 12th. Minimum temperatures between 18° and 22° were recorded in the northeastern Texas onion-growing districts. This cold spell was preceded by an unusually mild winter which advanced the season of most truck crops. The freeze damage report of March 22 [11] gives "only slight damage in South Texas, although harvest may be delayed and quality impaired. Loss of plants in North Texas appears to have run heavy according to early reports."

Temperatures were also unusually low in California during the winter of 1932–33. A minimum of 12° F. killed onion seedlings just emerged from the soil, while seedling plants of the California Early Red and Italian Red varieties that had been set in the field were not badly injured and very few if any were killed. Mature bulbs that had been planted for seed and not yet covered were so badly damaged in many cases that the fields were abandoned. From these meager reports it is evident that the most tender varieties in this test are capable of surviving quite low temperatures.

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[8] UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU. CLIMATOLOGICAL DATA. TEXAS SECTION. U. S. Dept. Agr., Weather Bureau Climatological Data 17, no. 1, Texas, 8 pp. January 1930.

[9] BUREAU OF AGRICULTURAL ECONOMICS. FROST AND FREEZE DAMAGE TO TRUCK CROPS IN TEXAS AS REPORTED JANUARY 29, 1930. U. S. Dept. Agr., Bureau Agr. Econ., Div. of Crops and Livestock Estimates, 1 p., Jan. 29, 1930. [Mimeographed.]

[10] UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU. CLIMATOLOGICAL DATA. TEXAS. U. S. Dept. Agr., Weather Bureau Climatological Data 19, no. 3, Texas, (35(3): 17–24). March 1932.

[11] ——— BUREAU OF AGRICULTURAL ECONOMICS. FREEZE DAMAGE TO SOUTHERN VEGETABLES. U. S. Dept. Agr., Bureau Agr. Econ., Division of Crop and Livestock Estimates, 3 pp. March 22, 1932. [Mimeographed.]

Results from five other localities where the same strains of onions were grown (Davis, Calif.; Logan, Utah; McGuffey, Ohio; Arlington Experiment Farm, Rosslyn, Va.; and Amherst, Mass.) indicate that the freeze was not the primary cause of splits and doubles, for in some of these places no frost occurred after the plants were set in the field. Growth conditions preceding or following the freeze probably play a more important part in the production of doubles and splits than the freeze itself. Preliminary observations of the 1934 crop of the same varieties at Winter Haven, Tex., show a greater percentage of doubles and splits for most of the varieties than was present in the 1933 crop, and no freezes of any consequence occurred during the 1934 season.

Varieties grown in the different locations have reacted differently as regards the percentage of doubles and splits. For example, Sweet Spanish in other locations produced a much larger percentage of doubles than at Winter Haven. Crystal Wax seemed to be especially susceptible to doubling under the environmental conditions at Winter Haven in 1933 and 1934, for this variety produced more doubles and splits than any other. At other locations, however, it was not among the varieties with the largest percentage of doubles.

"Multipliers" were, no doubt, basically in the same class as doubles and splits and differed only in that more axillary buds were stimulated into development at approximately the same time and were not enclosed by a leaf sheath. It is also probable that in these plants the originally encircling leaf bases were completely killed by the freeze although the stem plate survived. Reasoning from results of studies of growth stimulation in the onion by Boswell,[12] subsequent desiccation would allow air access to the stem plate, thereby stimulating development of the latent axillary buds.

The low percentage of seed stalks is probably the result of rather high mean temperature before and after the freezes and the short duration of the low temperatures. Miller's work [13] with mature bulbs indicated that mean temperatures of 56° to 60° F. largely prevented the production of seed stalks.

SUMMARY

Fifty-five strains representing 20 varieties of the important types of onions grown in the United States were grown at Winter Haven, Tex., and during early February 1933, while in a vigorously vegetative condition, were subjected to minimum temperatures of 18°, 21°, 34°, 26°, and 32° F. on successive days. Subsequent weather was favorable for recovery and renewed growth. A study of the material in early May disclosed the following points of interest:

More of the plants were killed in the Yellow Bermuda, Crystal Wax, California Early Red, Italian Red, Extra Early Yellow, Prizetaker, and Sweet Spanish varieties than in the domestic varieties such as Southport White Globe, Southport Yellow Globe, Southport Red Globe, Yellow Globe Danvers, White Portugal, Red Wethersfield,

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[12] BOSWELL, V. R. INFLUENCE OF THE TIME OF MATURITY OF ONIONS UPON THE REST PERIOD, DORMANCY AND RESPONSES TO VARIOUS STIMULI DESIGNED TO BREAK THE REST PERIOD. Amer. Soc. Hort. Sci. Proc. (1923) 20: 225–233. 1924.

[13] MILLER, J. C. EFFECT OF TEMPERATURE UPON THE CHARACTER OF GROWTH OF MATURE ONIONS. Amer. Soc. Hort. Sci. Proc. (1932) 29: 514–516. 1933.

Yellow Strasburg, Ebenezer, Ohio Yellow Globe, and Australian Brown.

Crystal Wax had the largest percentage of "doubles", and in general the flatter varieties had more doubles than the round or globe varieties.

"Multipliers" were more prevalent in the Yellow Bermuda and Italian Red varieties.

Seed stalks were very few in number but greatest in the Crystal Wax variety.

The differences observed between strains of a given variety would seem to indicate that the resistance to freezing and doubling were partially inherent and should be given consideration by plant breeders and seedsmen in their onion breeding or selection programs.

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